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Abstract

The present paper presents a theoretical analysis of the most important aspects of the Third Package introduced in January 1993 as an attempt to promote EU air transport competition. The paper analyses the strategic effects that arise from repeated interactions among oligopolists given the specific features of the airline industry. In particular, the paper gives some insights into why European flag-carriers seem reluctant to fully exploit the more liberal regulatory rules which provide larger entry opportunities into new EU markets. To this end, we present a model which shows under which conditions the European airline industry is more likely to sustain a noncooperative "mutual forbearance" equilibrium. (JEL L12,L13,L43,L93)

Key words: European Airline Liberalisation, Hub-and-Spoke Networks, Repeated Game, Tacit Collusion.

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I Introduction

An incumbent firm may preclude entry by a rival into a market by attacking this rival in (all) the other markets in which the rival already operates. This is not an unfamiliar result to economists (Kahn [1950], Edwards [1955]). When one firm might be better off by avoiding another's "territory" for fear of retaliation, we may end up in a "mutual forbearance" equilibrium for the industry. This kind of equilibrium is more likely to happen when oligopolists compete in different markets and meet each other repeatedly (Bernheim & Whinston [1990]).

The airline industry provides an ideal framework to study these strategic issues. Empirical research suggests that strategic effects play a substantial role in the conduct and performance of the U.S. airline industry (Evens & Kessides [1991,1993], Barla [1992]). However, there has been little theoretical work to relate these strategic effects to specific features of the industry, in particular the fact that airlines operate networks. It has been recognised that the structure of airlines' network plays an important role in understanding airline economics (Pavaux [1984], Levine [1987]). Recent research has confirmed that hub-and-spoke [hereafter, h-a-s] networks operated by airlines are an efficient way to organise production (e.g., Encaoua & Perrot [1991]) and that the effects of competition may have substantial externalities throughout these networks (Brueckner & Spiller [1991], Zhang & Wei [1993]).

Using a similar approach to Brueckner & Spiller [1991], Nero [1994] has provided a framework for analysing some aspects of intra-European airline competition. Intra-European airline competition is modelled in the light of the new regulatory measures introduced as an attempt to promote competition in intra-EU air transport (the so-called Third Package[1] in force as of January 1993). This paper extends the previous paper in the following directions. First, dynamics are introduced to take strategic effects into account. Second, the model allows for an explicit treatment of the most important air freedom rights governing international airline competition: (Fifth)seventh freedom and cabotage freedom rights. In the

[1]Published in OJ L240, No 2411/92/EEC, 24.8.92.

airline's jargon the (fifth)seventh freedom traffic right would allow, e.g., Air France to serve the intra-European (Paris)-Frankfurt-Milan route, while the cabotage right would allow Air France to serve the domestic Milan-Rome route. Consequently, a cross-national open-entry policy is provided under these air freedom rights. Cabotage rights will be granted in April 1997 and correspond to **complete liberalisation** of the European airline industry[2]. Seventh freedom rights correspond to the present phase of liberalisation, which I call **partial liberalisation**.

Unlike the developments following the U.S. airline deregulation[3] in October 1978, recent developments in the European airline industry suggest that European airlines made little use of the new entry opportunities provided by partial liberalisation. This lack of entry is acknowledged by leading airline specialists[4] as well as by the Association of European Airlines [AEA][5]. Although there may be several reasons why European flag-carriers did not fully exploit the new entry opportunities (economic downturn, lack of demand or natural monopoly in thin markets, etc.) I suspect that strategic interactions arise when airlines repeatedly face each other in different markets within a network[6]. When Air France makes use of its seventh freedom right on the Frankfurt-Milan route, Lufthansa and Alitalia's market shares are likely to be affected by Air France's entry. Since Air France operates simultaneously the Paris-Milan and Paris-Frankfurt routes, as a result of past bilateral agreements, the opportunity for its rivals to retaliate in these markets is large: Lufthansa and Alitalia could retaliate in two of Air France's markets using their seventh freedom rights. As a result, Air France may simply be better off not serving the Frankfurt-Milan market. A similar reasoning may

[2]Complete liberalisation would make the European airline industry legally equivalent to the deregulated domestic U.S. airline industry.

[3]See Bailey & Panzar [1981] for a study of U.S. markets during the transition to deregulation. According to these authors a total of 449 nonstop routes were added during the period between July 1, 1978, and July 1,1979.

[4]See, e.g., Geoffrey H. Lipman's (President of the World Travel and Tourism Council) comments in the International Herald Tribune, 1 February 1994.

[5]See AEA Annual Yearbook 1994, p.6.

[6]This assumption has found recent empirical support in the conduct of the U.S. airline industry, see Evens & Kessides [1991,1993], Barla [1992].

be applied when Air France makes use of its cabotage rights, say on the Milan-Rome route. This example illustrates the rationale of this paper. To be more explicit, I want to investigate under which conditions a "mutual forbearance" equilibrium can be sustained in the case of partial liberalisation and complete liberalisation of the European airline industry. In that respect, this paper is an attempt to provide a theoretical analysis of the Third Package. Clearly, the issues addressed in this paper could be relevant to EU anti-trust policy.

The sketch of the model is as follows. Three hub-and-spoke [h-a-s] *flag-carriers*[7] meet each other infinitely in several geographical markets. Depending on the regulatory regime (partial or complete liberalisation), each airline has either the option to stick to past bilateral agreements, obtaining duopoly profits on the intra-European markets, or the option to enter into new markets and to expand its operations. Each flag-carrier has to compare its gains from sticking to past bilateral agreements (tacit collusion) and its gains from deviating given that, in case of deviation, a trigger strategy is applied. In solving the games, one for each regulatory regime, I will be looking for subgame perfect equilibria. Since infinitely repeated games have many different equilibrium outcomes (the Folk Theorem), I compare the *most* collusive equilibrium outcomes that can be sustained under each regulatory regime. I therefore define, for each regime, a range of discount factors over which noncooperative collusive outcomes can be sustained by the trigger strategy. The regulatory regime which has the *lower minimum* discount factor is, ceteris paribus, more able to support the "mutual forbearance" equilibrium described above.

The results of the paper are driven by the network h-a-s structure and by the fixed costs associated with entry. I assume that fixed costs associated with entry into a rival's domestic leg are larger than those associated with entry into an intra-European leg. In the latter leg the

[7] Only flag-carriers operating *scheduled* air passenger services are considered. Scheduled services make up slightly more than half the total traffic volume in Europe, as measured in passenger-kilometres. In passenger numbers, the share is much greater, at about 76%, the difference being due to an average scheduled trip length of 675km compared with over 2'000km for *charter*. See AEA Yearbook 1993.

flag-carrier is already present in both end points, while in the former the flag-carrier must add a new station to its network. For sufficiently low fixed costs, complete liberalisation provides, in equilibrium, less opportunity to sustain collusion. In other words, when fixed costs are low, flag-carriers are more likely to sustain noncooperative collusive outcomes under partial liberalisation of the European airline industry. When fixed costs are nil, the range of discount factors over which flag-carriers can sustain collusive equilibria is *always* larger under partial liberalisation.

The paper is organised as follows. Section II introduces the model. The assumptions are discussed in Section II.1 with a particular focus on the description of the h-a-s network structure. Section II.2 proposes the specifications for the demand and cost functions. The main results of the paper are presented in Section III. Section IV concludes.

II The Model

II.1 Assumptions and Model Set-up

The European airline industry has several interesting features. First, European city-pair markets are typically operated by a few flag-carriers[8]. Second, European flag-carriers are likely to recognise their mutual interests and interdependence throughout the markets (linked networks) where they operate because of their long-standing relations in the business[9]. Third, because of heavy past regulations and/or geographical characteristics of European countries, most European flag-carriers operate a h-a-s network centred in one major (hub) airport. Given these features, an interesting question arises: Under which circumstances does a flag-carrier prefer to guarantee itself "collusive" noncooperative duopoly profits on the intra-European markets rather than to meet more competitors on more intra-European routes (i.e., to make use of the new air freedom

[8] See AEA Yearbook 1994, p.21.

[9] Very powerful and well-organised trade associations such as IATA or AEA certainly facilitate recognition of their mutual interdependence.

rights provided by the Third Package) ? The game-theoretic model used to answer this question allows for an explicit treatment of the strategic effects arising among oligopolist flag-carriers. In addition, the model takes the nature of an airline h-a-s network and the European regulatory environment into account. The main (static) assumptions of the model are presented first (ASSUMPTION I) with a particular focus on the description of the h-a-s network structure. The (dynamic) assumptions and description of the games follow (ASSUMPTION II).

ASSUMPTION I:

- Three identical flag-carriers (airlines), $f = \mathcal{A}, \mathcal{B}, \mathcal{C}$, operate scheduled air passenger services on a given h-a-s network. Note that one must consider at least three flag-carriers to provide the minimum framework for analysing seventh freedom and cabotage airline competition. Flag-carriers are thought of as single-product firms that operate in a number of distinct geographic markets (multi-market firms).

- Markets are not identical. This assumption leaves room for the provisions granted by the Third Package of regulatory rules, which provides flag-carriers with the ability to maintain, until April 1997, some monopoly markets (usually domestic markets) and to compete with incumbent flag-carriers in other markets (usually duopoly intra-European markets).

- As a result of government regulation or some other insurmountable barrier to entry (high fixed and/or sunk costs), additional entry throughout the network by non-incumbent airlines is ruled out[10].

- Flag-carriers provide a *homogeneous* service. Quantities are airlines' strategy variable. I interpret a choice of quantity as that of a

[10]Borenstein [1992] argues that, although there are charter companies or regional airlines that may be able to enter into some markets, "the most likely potential entrants on any of the major European city-pair markets are scheduled carriers that currently serve both end points of the market from their own base city."

scale of operation or capacity[11]. It is assumed that the scale of operation is quickly and easily adjusted[12]. This occurs because of the existence of an active and competitive rental market for aircraft.

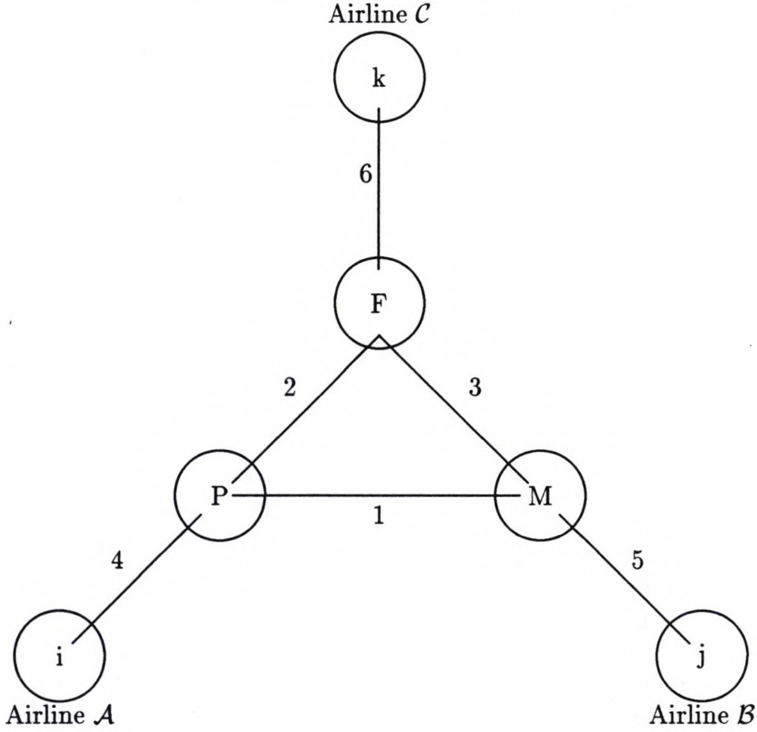
- For computational convenience, I assume symmetric flag-carriers, i.e., using the same technology and operating symmetric networks. In particular, each flag-carrier operates aircraft on *legs*, l, of equal distance.

The simplest h-a-s network involving three flag-carriers is represented in Figure 1. For historical reasons, Airline $\mathcal{A}$ operates aircraft on legs $l = 1, 2, 4$ which connect cities i, P, M, and F. P is the central point (hub) of Airline $\mathcal{A}$'s network (generally country $\mathcal{A}$'s capital). Leg $l = 4$ connects cities i and P and is a purely domestic leg, i.e., cannot be operated by another incumbent flag-carrier. The legs $l = 1, 2$ are the intra-European legs and on these legs Airline $\mathcal{A}$ competes simultaneously with Airline $\mathcal{B}$ and Airline $\mathcal{C}$. Airline $\mathcal{B}$ operates aircraft on legs $l = 1, 3, 5$, connecting cities j, M, P, and F. Airline $\mathcal{B}$'s domestic leg, $l = 5$, connects cities j and M. On the intra-European leg $l = 3$, Airline $\mathcal{B}$ competes with Airline $\mathcal{C}$. Finally, Airline $\mathcal{C}$ operates aircraft on legs $l = 2, 3, 6$, connecting the cities k, F, P and M. Airline C's domestic leg, $l = 6$, connects cities k and F. In this simple symmetric network, each airline is in contact with another competitor on one intra-European leg (or two points). Airline $\mathcal{A}$ and Airline $\mathcal{B}$ are in contact on leg $l = 1$,

[11] I shall refer to Kreps & Scheinkman [1983] in order to justify this quantity game. Airline competition can be modelled as a two-stage process, where airlines set capacity in the first stage (long run investment in capacity) and compete in price in the second stage. Kreps & Scheinkman [1983] show that when the capacities chosen in the first stage correspond to the Cournot output levels, in the second stage firms name the Cournot price. Therefore, even if airlines seem to compete in price, Kreps & Scheinkman's results provide support for the use of a quantity game. Notice that Cournot behaviour in the airline industry has found empirical support in the literature, see for example Brander & Zhang [1990,1993].

[12] In fact, in a dynamic version of the Kreps & Scheinkman's paper, Benoit & Krishna [1987] have shown that when duopolists have the ability to continually adjust their capacity levels or can adjust their capacity levels quickly, they may be able to earn noncooperative collusive profits without building excess capacity.

Figure 1: Three Linked H-a-s Networks with One Domestic Leg ($N = 1$).



while Airline $\mathcal{A}$ and Airline $\mathcal{C}$ are in contact on leg $l = 2$. Airline $\mathcal{B}$ and Airline $\mathcal{C}$ are in contact on leg $l = 3$. Therefore,

- Intra-European legs, $l = 1, 2, 3$, directly connect hub airports,
- Domestic legs, $l = 4, 5, 6$, connect "peripheral" cities (i, j and k, respectively) to a hub airport (P, M and F, respectively) and,
- Each "peripheral" city is connected to another country with a one stop service at least.

Figure 1 corresponds to a very simple h-a-s network. An interesting generalisation of Figure 1 is to consider a h-a-s network with N different domestic legs ($i, j, k = 1, .., N$). With N domestic legs, each flag-carrier would operate aircraft on $L = N + 2$ legs. From now on, I consider this general set-up.

<u>ASSUMPTION II</u>:

- We assume that flag-carriers, f=$\mathcal{A}$,$\mathcal{B}$,$\mathcal{C}$, operate in discrete time with an infinite horizon and a common discount factor, $\delta = 1/(1 + r)$, where r is the constant interest rate. Furthermore, complete information, in particular full knowledge of each other's profit functions, and perfect monitoring are assumed.
- A trigger strategy described by Friedman [1971] is used. The motives for choosing a trigger strategy are that (a) it is simple to characterise, (b) it is easier to implement than any other more sophisticated strategy[13] and (c) it seems reasonable for the airline industry. Flag-carriers face repeated mutual entry threats throughout the network according to the regulatory regime. Each flag-carrier f has an action set A_f ={to enter, not to enter} and a pure strategy set S_f ={to enter if a deviation has been observed, to stick

[13] Abreu [1988] has shown that the trigger strategy designed by Friedman in general uses a non-optimal punishment.

to the bilateral agreements otherwise)}. Airlines move simultaneously. The stage game (one shot-game) of the repeated games is equal under both regulatory regimes and is the following: In period t, Airline f sticks to the existing bilateral agreements so long as no entry into Airline f's markets has been observed in the previous period. If an entry is observed in period t, Airline f retaliates in the following period by entering into its rival incumbents' markets and producing at the Cournot-Nash outcome for the remainder of the game. Irreversible and permanent entry together with reversion to the Cournot-Nash outcome is a particularly "grim" trigger strategy. Note that irreversible entry rules out strategies such as hit-and-run behaviour. The solution concept used is that of subgame perfect equilibrium and, given the symmetry (and stationarity) of the model, I look for optimal stationary symmetric-payoff equilibria.

In a first repeated game I consider **partial liberalisation** of the European airline industry so that cabotage rights are not granted to flag-carriers. Given the network of Figure 1, each flag-carrier has the *option* to enter on one new seventh freedom (intra-European) leg and to compete there with the other two incumbent flag-carriers. As an example, consider Airline $\mathcal{A}$'s strategy in the framework of Figure 1. Airline $\mathcal{A}$ deviates[14] in period t from previous bilateral agreements by entering the FM market (seventh freedom leg), which is operated by incumbent Airline $\mathcal{B}$ and Airline $\mathcal{C}$ as a result of past bilateral agreements. Following the entry, Airline $\mathcal{B}$ and Airline $\mathcal{C}$ retaliate in period $t+1$ by entering on the PF and PM markets. Consequently, the additional profit which arises following Airline $\mathcal{A}$'s deviation should be compared with the losses incurred in the following periods when, as a result of (rational) retaliation, each flag-carrier operates aircraft on all intra-European legs. Notice that, since airlines operate on many markets, costs and benefits following a deviation do not raise proportionally. In fact, following the defection in

[14] In deciding whether to deviate, Airline $\mathcal{A}$ assigns probability zero to a rival deviating in the same period.

one market (FM), Airline $\mathcal{A}$ is simultaneously punished in two markets (PF and PM).

In a second game, I assume a **complete liberalisation** of the European airline industry so that cabotage rights are now granted. Now, each flag-carrier has the option to enter on one seventh freedom leg and $2N$ domestic (cabotage freedom) legs. It is assumed that, since a flag-carrier expects to be punished in all markets (throughout its network), it will consider deviating in all markets, i.e., a harsher punishment structure is used. One might object to this simultaneous large scale entry on the grounds that a more gradual entry strategy is more plausible in the European airline industry. Clearly, this latter scenario should be considered as a competitive benchmark under complete liberalisation[15]. Notice that during the deviation period, Airline $\mathcal{A}$ enjoys duopoly profits on the former (domestic) monopoly markets operated by Airline $\mathcal{B}$ and Airline $\mathcal{C}$, while punishment implies that all markets in the network are operated by all flag-carriers.

For each regulatory regime, sticking to the previous bilateral agreements, and producing the corresponding collusive output in each period, is a subgame perfect equilibrium through trigger strategies in the infinite horizon game, if Airline $\mathcal{A}$'s incentive constraint satisfies:

$$\pi_{\mathcal{A}}^{dev} + \sum_{t=1}^{\infty} \delta^t \pi_{\mathcal{A}}^{pun} \leq \sum_{t=0}^{\infty} \delta^t \pi_{\mathcal{A}}^{col}, \tag{1}$$

or, in a more informative way,

$$\pi_{\mathcal{A}}^{dev} - \pi_{\mathcal{A}}^{col} \leq \frac{\pi_{\mathcal{A}}^{col} - \pi_{\mathcal{A}}^{pun}}{r},$$

where $\pi_{\mathcal{A}}^{col}$ is Airline $\mathcal{A}$'s per period profit without entry, $\pi_{\mathcal{A}}^{dev}$ is Airline $\mathcal{A}$'s per period profit following its entry and $\pi_{\mathcal{A}}^{pun}$ is Airline $\mathcal{A}$'s per period

[15]Therefore, not only is it assumed that the scale of operation is easily adjusted, it is also assumed that flag-carriers operate without capacity constraint on airport landing slots. While it has been recognised that most flag-carriers bear aircraft excess capacity, airport landing slots may be an important issue in some busy European airports (see Borenstein [1992]). See also Footnote 12.

profit from retaliation. In what follows, I compare the *most* collusive equilibrium outcomes that can be sustained under each regulatory regime. Given (1), the regulatory regime which has the *lower minimum* discount factor is, ceteris paribus, more likely to support the "mutual forbearance" equilibrium described above. In order to derive useful results, the following specifications are adopted. These specifications borrow heavily from previous papers in transportation economics.

II.2 Specifications

Assume that flag-carriers face a linear symmetric demand across city-pairs (markets). The inverse demand function for round-trip travel in any given city-pair market xy is given by $P(Q_{xy})$, with Q_{xy} representing the number of round-trip passengers in the market xy. Note that Q_{xy} represents the number of passengers travelling from city x to city y and back, plus the number of passengers travelling from city y to city x and back. The demand for international services is limited in the sense that $D(Q_{ij}) = D(Q_{ik}) = D(Q_{jk}) = 0$. Put differently, there is no demand between cross-border "peripheral" cities. While gaining in simplicity[16], the model captures the following feature: Most intra-European traffic flows stop at hub airports. This is particularly relevant for central EU countries, where capitals mostly attract leisure and business travellers. In order to keep the model as simple as possible, I also assume that there is no demand between "peripheral" cities within the same country, i.e., $D(Q_{ii'}) = D(Q_{kk'}) = D(Q_{jj'}) = 0$, for all ii', kk', jj' [17]. In addition, because the change of carrier implies higher risks of missing a connection (often associated with the change of terminal in hub airports and/or the lack of flight coordination between carriers) or of losing baggage, a passenger originating his journey in i and willing to fly to city F, for example, is assumed to choose the same flag-carrier, i.e., Airline $\mathcal{A}$. These

[16] With n the number of cities, the total city-pairs would be $n(n-1)/2$. When $n = 6$, as Figure 1 suggests, we have potentially 15 different city-pairs. With the previous assumption, the model is reduced to 12 different city-pairs.

[17] This is more likely to happen when distance between "peripheral" cities is short enough for passengers to prefer a different mode of transportation.

travellers' preferences ensure that each airline is able to transport their *connecting* passengers on the intra-European leg. Airline $\mathcal{A}$, for example, carries all the Q_{iF} and Q_{iM} passengers. Similarly, Airline $\mathcal{B}$ and Airline $\mathcal{C}$ carries all the Q_{jP}, Q_{jF} and Q_{kP}, Q_{kF} travellers, respectively. More specifically, let the inverse demand function be:

$$P(Q_{xy}) = \alpha - \beta Q_{xy}, \quad \text{with } \alpha \text{ and } \beta > 0. \tag{2}$$

The intercept of the demand function in (2), α, is identical for all city-pair markets xy. This is equivalent to assuming that the cities are similar in size. By eliminating differences in size between cities, this assumption allows us to highlight the effects of network and market structure on the (collusive) equilibria in two different liberalisation settings.

The assumption of common distance of the legs of the network implies a common cost function, $C_l(Q_l)$, applying to each of the legs l in the network. This cost function gives the round-trip cost of carrying Q_l travellers on one leg. H-a-s networking implies that Q_l represent both *local* as well as *connecting* (i.e., with the same origin but with different destinations) passengers. On the leg connecting city i to city P of Figure 1, for example, Airline $\mathcal{A}$'s aircraft carry both local, i.e., i to P passengers, as well as connecting passengers. In this case, all traffic Q_l routing through this leg corresponds to $Q_{iP} + Q_{iF} + Q_{iM}$. Similarly, all traffic transported by Airline $\mathcal{A}$'s aircraft on the intra-European leg PM, for example, is composed of the local PM traffic, as well as all the connecting traffic from the "peripheral" cities to M, i.e., $\sum_{i=1}^{N} Q_{iM}$. The cost function applying to each of the legs l allows for increasing returns to density[18] stemming from hubbing operations. Consequently, $C_l(Q_l)$ satisfies the following properties: $C_l(Q_l) > 0, C_l'(Q_l) > 0$ and $C_l''(Q_l) \leq 0$. Following Brueckner & Spiller [1991], a general specification could be

[18]Returns to density arise when an increase of the volume of transportation services, within a given network, is more important than the associated increase in costs. See Caves et al. [1984].

provided by:

$$C = \sum_{l}^{L} C_l(Q_l) = \sum_{l}^{L} \theta Q_l - \gamma Q_l^2, \tag{3}$$

where C is the additive cost function for each flag-carrier, Q_l is the traffic volume of the relevant city-pair markets routing through leg l, L is the total number of legs operated by the relevant flag-carrier, $\theta > 0$, $\gamma \geq 0$ allowing for increasing returns to density with $\theta/\gamma > Q_l$. Constant returns to density imply $\gamma = 0$. It has been argued that constant returns to density are likely to appear once the minimum efficient traffic density level is reached (see Oum & Tretheway [1992]). Let us assume for the sake of simplicity that this efficient traffic density level is reached throughout the network, so that $\gamma = 0$[19]. Therefore, the marginal cost per leg is constant and equal to θ.

In the h-a-s network suggested by Figure 1, an airline has the option to enter into two different types of legs: The intra-European leg or the purely domestic leg. From the cost point of view, entry into a leg where an airline already operates both end points from its own h-a-s airport should *not* be treated like entry into a leg where one (or both) of the end points is not operated, which arises when a flag-carrier enters into a rival's pure domestic leg (see Figure 1). In this latter case, the airline has to set ground facilities at the new station, advertise its service to consumers who are less likely to be aware of the existence of the new service, and so on, making entry comparatively more costly. Many authors, in particular Levine [1987], have stressed this feature of airline network economics. Consequently, entry is modelled in the following way: Fixed costs associated with entry into the intra-European leg are supposed to be *nil*, while they are equal to F when entry occurs into a domestic leg[20].

[19] Cost-based linkages across markets (costs complementarity) exist as long as $\gamma \neq 0$, which considerably complicates the analysis of the effects of network and markets structure on the (collusive) equilibria. See Brueckner & Spiller [1991] for the effects of competition in airline h-a-s network with increasing returns to density.

[20] It could be argued that sunk costs K are incurred when flag-carriers begin service on a new leg. Since K can be expressed as a fraction of F ($K = sF$ with $s \leq 1$), I assume for simplicity's sake that $s = 1$, so that $K = F$.

III Results

III.1 GAME I: Partial Liberalisation

Given the symmetry of the model, I focus on equilibria which yield symmetric payoffs to the three airlines. Let us concentrate on the Airline $\mathcal{A}$'s equilibrium values. Consider first the **most** collusive equilibrium outcome, i.e., when no entry is observed on the intra-European FM leg. In that case, once airlines collude with a staying-out strategy, each airline would be better off with setting the monopoly quantity (maximum level of collusion) in markets with contact, i.e., FM, PM and PF. This is a likely outcome if the flag-carriers can use pre-play communication to focus beliefs on the best self-enforcing (nonbinding) agreement. Under the previous assumptions (in particular, no demand between domestic and foreign "peripheral" cities), Airline $\mathcal{A}$'s city-pair markets are: iP, iM, iF, PM and PF, with $i = 1, .., N$. Airline $\mathcal{A}$'s profit function, $\pi_{\mathcal{A}}$, can be expressed as

$$\begin{aligned}\pi_{\mathcal{A}} &= \sum_{i=1}^{N} P(Q_{iP})Q_{iP} + \sum_{i=1}^{N} P(Q_{iM})Q_{iM} + \sum_{i=1}^{N} P(Q_{iF})Q_{iF} \\ &\quad + P(Q_{PM})q_{PM}^{\mathcal{A}} + P(Q_{PF})q_{PF}^{\mathcal{A}} - C_{l=pm}(q_{PM}^{\mathcal{A}} + \sum_{i=1}^{N} Q_{iM}) \\ &\quad - C_{l=pf}(q_{PF}^{\mathcal{A}} + \sum_{i=1}^{N} Q_{iF}) - \sum_{i=1}^{N} C_{l=ip}(Q_{ip} + Q_{iF} + Q_{iM}),\end{aligned}$$

or

$$\begin{aligned}\pi_{\mathcal{A}} &= \sum_{i=1}^{N}(\alpha - \beta Q_{iP})Q_{iP} + \sum_{i=1}^{N}(\alpha - \beta Q_{iM})Q_{iM} + \sum_{i=1}^{N}(\alpha - \beta Q_{iF})Q_{iF} \\ &\quad + (\alpha - \beta(q_{PM}^{\mathcal{A}} + q_{PM}^{\mathcal{B}}))q_{PM}^{\mathcal{A}} + (\alpha - \beta(q_{PF}^{\mathcal{A}} + q_{PF}^{\mathcal{C}}))q_{PF}^{\mathcal{A}} - \theta(q_{PM}^{\mathcal{A}} + \\ &\quad \sum_{i=1}^{N} Q_{iM}) - \theta(q_{PF}^{\mathcal{A}} + \sum_{i=1}^{N} Q_{iF}) - \sum_{i=1}^{N} \theta(Q_{iP} + Q_{iF} + Q_{iM}),\end{aligned} \tag{4}$$

where $Q_{PM} = q_{PM}^{\mathcal{A}} + q_{PM}^{\mathcal{B}}$ and $Q_{PF} = q_{PF}^{\mathcal{A}} + q_{PF}^{\mathcal{C}}$. From (4), it can be observed that Airline $\mathcal{A}$'s revenues are generated from its $3N+2$ markets, while its costs correspond to aircraft flown on $L = N + 2$ legs. Note that both PM and PF markets are simultaneously operated by Airline $\mathcal{B}$ and Airline $\mathcal{C}$. In these latter markets, joint profit maximisation is assumed. Solving the system of $3N+2$ first order conditions using the profit function (4) and the symmetry of the model, we obtain Airline $\mathcal{A}$'s optimal quantities:

$$q_{PM}^{\mathcal{A}} = q_{PF}^{\mathcal{A}} = \frac{(\alpha-\theta)}{4\beta} = \frac{S}{4\beta} \tag{5}$$

$$Q_{iP} = \frac{(\alpha-\theta)}{2\beta} = \frac{S}{2\beta} \qquad \text{for} \quad i = 1,..,N \tag{6}$$

$$Q_{iM} = Q_{iF} = \frac{(\alpha-2\theta)}{2\beta} = \frac{(S-\theta)}{2\beta}, \qquad \text{for} \quad i = 1,..,N \tag{7}$$

where $S \equiv \alpha - \theta$, and $S > \theta$. Notice that the symmetric structure reduces Airline $\mathcal{A}$'s maximisation problem to a three variables problem[21]. Given (5)-(7), Airline $\mathcal{A}$'s static profit (4) can be expressed as a direct function of quantities/capacities. It can be shown that, in equilibrium

$$\pi_{\mathcal{A}}^{col} = \frac{1}{\beta}\Big(\frac{S}{2}\Big)^2(N+1) + \frac{1}{\beta}\Big(\frac{S-\theta}{2}\Big)^2 2N. \tag{8}$$

From (8), it appears that profit increases as the number of domestic legs, N, increases.

Next consider the case where Airline $\mathcal{A}$ deviates and operates aircraft on the FM leg. Given our assumptions, it appears that (a) Airline $\mathcal{A}$'s revenues are generated from $3N+3$ markets, while its costs correspond to aircraft flown on $L = N+3$ legs (b) no fixed costs are associated with entry into the FM market, since Airline $\mathcal{A}$ already serves both end points of the leg from its h-a-s airport (c) in the FM market Airline $\mathcal{A}$

[21] The model prevents arbitrage opportunities from arising, which is a useful requirement in a transportation model. In effect, in order to prevent arbitrage opportunities, fares must be set such that the sum of the individual fares for the two legs of the trip (e.g., iP plus PM) is larger than the fare for a given city-pair market involving one stop (e.g., iM). If this were not the case, it would be profitable for the traveller to purchase the tickets separately. It can be shown that arbitrage opportunities are prevented throughout the paper.

competes with Airline $\mathcal{B}$ and Airline $\mathcal{C}$ so that $Q_{FM} = q^{\mathcal{A}}_{FM} + q^{\mathcal{B}}_{FM} + q^{\mathcal{C}}_{FM}$. Moreover, Airline $\mathcal{A}$'s total volume of traffic transported on the FM leg corresponds to the *local*, $q^{\mathcal{A}}_{FM}$, traffic only. Given that Airline $\mathcal{B}$ and Airline $\mathcal{C}$ each produce the (collusive) monopoly quantity in the FM market, Airline $\mathcal{A}$'s optimal cheat strategy is to enter at its best-response quantity (i.e., to maximise profit on the residual demand). This occurs at

$$q^{\mathcal{A}}_{FM} = \frac{(\alpha-\theta)}{4\beta} = \frac{S}{4\beta}. \tag{9}$$

Given (5)-(7) and (9), it can be shown that the reduced form of the static Airline $\mathcal{A}$'s deviation profit is equal to

$$\pi^{dev}_{\mathcal{A}} = \frac{1}{\beta}\Big(\frac{S}{2}\Big)^2(N + \frac{5}{4}) + \frac{1}{\beta}\Big(\frac{S-\theta}{2}\Big)^2 2N. \tag{10}$$

The difference between (10) and (8) corresponds to the additional short run profit associated with the entry in the FM leg and is equal to $S^2/16\beta > 0$.

After Airline $\mathcal{A}$'s deviation, it is assumed that Airline $\mathcal{B}$ and Airline $\mathcal{C}$ retaliate and enter simultaneously in the PF and PM markets. Consequently, after Airline $\mathcal{A}$'s deviation, a repeated static Cournot game is played on the intra-European FM, PF and PM markets. Now $Q_{PM} = q^{\mathcal{A}}_{PM} + q^{\mathcal{B}}_{PM} + q^{\mathcal{C}}_{PM}$ and $Q_{PF} = q^{\mathcal{A}}_{PF} + q^{\mathcal{B}}_{PF} + q^{\mathcal{C}}_{PF}$. Given the symmetric structure of the model, we focus on the symmetric Cournot-Nash equilibria where $q^{\mathcal{A}}_{PM} = q^{\mathcal{B}}_{PM} = q^{\mathcal{C}}_{PM}$, $q^{\mathcal{A}}_{PF} = q^{\mathcal{B}}_{PF} = q^{\mathcal{C}}_{PF}$ and $q^{\mathcal{A}}_{FM} = q^{\mathcal{B}}_{FM} = q^{\mathcal{C}}_{FM}$. Solving the proper $3N + 3$ first order conditions yields Airline $\mathcal{A}$'s optimal quantities:

$$q^{\mathcal{A}}_{PM} = q^{\mathcal{A}}_{PF} = q^{\mathcal{A}}_{FM} = \frac{(\alpha-\theta)}{4\beta} = \frac{S}{4\beta} \tag{11}$$

$$Q_{iP} = \frac{(\alpha-\theta)}{2\beta} = \frac{S}{2\beta} \qquad \text{for} \quad i = 1, .., N \tag{12}$$

$$Q_{iM} = Q_{iF} = \frac{(\alpha-2\theta)}{2\beta} = \frac{(S-\theta)}{2\beta}. \qquad \text{for} \quad i = 1, .., N \tag{13}$$

Not surprisingly, for a given nonstop city-pair market, the equilibrium quantity provided in a triopoly market, $3S/4\beta$, is larger than the quantity provided by the monopolist, $S/2\beta$. Note also that (12)-(13) are identical to (6)-(7) since, in these markets, internal conditions have not changed. The result of the retaliation is that Airline $\mathcal{A}$ is "hurt" in *two* contested markets, PM and PF, since it produces the same quantity at a lower equilibrium price. Given (11)-(13), the reduced form of the static Airline $\mathcal{A}$'s punishment profit can be expressed as

$$\pi_{\mathcal{A}}^{pun} = \frac{1}{\beta}\Big(\frac{S}{2}\Big)^2(N + \frac{3}{4}) + \frac{1}{\beta}\Big(\frac{S-\theta}{2}\Big)^2 2N. \tag{14}$$

It can be shown that Airline $\mathcal{B}$ (or Airline $\mathcal{C}$) earns a greater profit by entering in $\mathcal{A}$'s markets than by staying where it is and maximising monopoly profit where it was doing so before. In other words, the threat is credible[22].

Finally, I am able to investigate under which conditions the trigger strategy forms a subgame perfect equilibrium. Using (8), (10) and (14), Airline $\mathcal{A}$'s incentive constraint (1) must satisfy the following inequality:

$$\frac{1}{\beta}\big(\frac{S}{2}\big)^2\Big(\frac{1-2\delta}{4(1-\delta)}\Big) \leq 0.$$

[22]It has been argued that when players can freely (unlimitedly) discuss their strategies in a pre-play communication (without making binding agreements), a coalition of players might arrange plausible, mutually beneficial deviations from Nash agreements (see Bernheim et al. [1987]). Consequently, one should investigate to what extent the trigger strategy described above forms a Coalition-Proof Nash equilibrium. One way to examine this complex issue is to consider the incentive of a coalition of two flag-carriers, say Airline $\mathcal{B}$ and Airline $\mathcal{C}$, to jointly renege on the punishment equilibrium implied by the trigger strategy following Airline $\mathcal{A}$'s deviation. Dynamic consistency (coalition-proof equilibrium) requires that Airline $\mathcal{B}$ and Airline $\mathcal{C}$ equilibrium payoffs not be dominated by another feasible punishment, e.g., to accommodate Airline $\mathcal{A}$'s entry. In other words, the agreement (equilibrium) which specified that Airline $\mathcal{B}$ and Airline $\mathcal{C}$ enter into Airline $\mathcal{A}$'s markets and play a Cournot game forever, should Airline $\mathcal{A}$'s initial entry be observed, must be a coalition-proof equilibrium for the proper (punishment) subgame. It is not difficult to show that this result always holds under partial liberalisation. Unfortunately, such a clear-cut result does not occur under complete liberalisation because of the fixed costs associated with entry into a domestic leg. However, it can be shown that it holds for a reasonable range of fixed costs.

This expression can be reduced to:

$$\delta_p \geq \frac{1}{2}.$$

Several comments are in order. First, the result is independent of the number of domestic legs, N, operated by each flag-carrier. This is due to the fact that partial liberalisation does not affect competition in the domestic legs when cost complementarities are absent (i.e., when $\gamma = 0$) and when all city-pair markets are of equal size. Second, given that Airline $\mathcal{A}$ cannot gain much from entry but has a great deal to lose, it is not surprising to find that δ_p provides large opportunity for collusion. Finally, the δ_p required for sustaining a noncooperative collusive outcome under partial liberalisation is independent of the underlying parameters of the demand and cost functions. This follows from the symmetry of the model.

III.2 GAME II: Complete Liberalisation

The same approach as in Section III.1 is followed except that now each flag-carrier might simultaneously enter into one seventh freedom leg and $2N$ rivals' domestic legs according to the repeated game described in Section II.1.

Let us first consider the case where each airline sticks to the existing bilateral agreements, i.e., where no use of seventh freedom and cabotage rights is made. This case is tantamount to the most collusive equilibrium outcome described in Section III.1, with Airline $\mathcal{A}$, for example, operating aircraft on $L = N+2$ legs, serving $3N+2$ different city-pair markets and setting the monopoly quantity in the PM and PF markets. Accordingly, Airline $\mathcal{A}$'s profit function is similar to (4), which implies that optimal quantities and profit are identical to (5)-(7) and (8).

Matters are quite different for the deviation and the punishment payoffs. Under complete liberalisation, Airline $\mathcal{A}$'s deviation implies that it operates aircraft on $L = 3N+3$ legs (instead of the previous $N+2$ legs) serving $9N+3$ different city-pair markets. Among the $9N+3$ markets operated by Airline $\mathcal{A}$, $3N$ are monopoly markets, $6N+2$ are duopoly markets and, finally, one market is simultaneously operated by the three flag-carriers. Since entry into a domestic leg is associated with fixed costs, F, a deviation implies that Airline $\mathcal{A}$ incurs fixed costs equal to $2NF$. As before, Airline $\mathcal{A}$'s optimal deviation strategy is to enter at its best-response quantity given that Airline $\mathcal{B}$ and Airline $\mathcal{C}$ each produce the collusive output in the FM market and the monopoly output in their previous domestic markets. It can be shown that Airline $\mathcal{A}$'s profit maximisation implies quantities (5)-(7), (9) and, in order to take the new opportunities of entry into account,

$$q_{kF}^{\mathcal{A}} = q_{jM}^{\mathcal{A}} = \frac{(\alpha-\theta)}{4\beta} = \frac{S}{4\beta} \quad \text{for} \quad k,j = 1,..,N \tag{15}$$

$$q_{kP}^{\mathcal{A}} = q_{kM}^{\mathcal{A}} = q_{jF}^{\mathcal{A}} = q_{jP}^{\mathcal{A}} = \frac{(\alpha-2\theta)}{4\beta} = \frac{(S-\theta)}{4\beta}. \quad \text{for} \quad k,j = 1,..,N \tag{16}$$

Given (5)-(7), (9), (15)-(16), the reduced form of the static Airline $\mathcal{A}$'s deviation profit can be expressed as

$$\pi_{\mathcal{A}}^{Dev} = \frac{1}{\beta}\Big(\frac{S}{2}\Big)^2\Big(\frac{6N+5}{4}\Big) + \frac{1}{\beta}\Big(\frac{S-\theta}{2}\Big)^2 3N - 2NF > 0. \tag{17}$$

After Airline $\mathcal{A}$'s deviation, it is assumed that Airline $\mathcal{B}$ and Airline $\mathcal{C}$ retaliate and simultaneously enter in all the markets throughout the network, i.e., they make use of their seventh freedom and cabotage rights granted under the complete liberalisation of the industry. As a consequence, after Airline $\mathcal{A}$'s deviation, a repeated static Cournot game is played on the $9N+3$ different city-pair markets, with each flag-carrier operating aircraft on $L = 3N+3$ legs. It is important to notice that, following the retaliation, Airline $\mathcal{A}$ is "hurt" in $3N+2$ contested markets, i.e., exactly all the markets it served prior to the deviation[23]. Under the

[23]This result should be contrasted with the partial liberalisation case, where Airline $\mathcal{A}$ was hurt in two markets.

symmetric Cournot-Nash equilibrium, Airline $\mathcal{A}$'s optimal quantities are

$$q^{\mathcal{A}}_{PM} = q^{\mathcal{A}}_{PF} = q^{\mathcal{A}}_{FM} = q^{\mathcal{A}}_{kF} = q^{\mathcal{A}}_{jM} = q^{\mathcal{A}}_{iP} = \frac{(\alpha-\theta)}{4\beta} = \frac{S}{4\beta}, \tag{18}$$

$$q^{\mathcal{A}}_{iM} = q^{\mathcal{A}}_{iF} = q^{\mathcal{A}}_{kP} = q^{\mathcal{A}}_{kM} = q^{\mathcal{A}}_{jF} = q^{\mathcal{A}}_{jP} = \frac{(\alpha-2\theta)}{4\beta} = \frac{(S-\theta)}{4\beta}, \tag{19}$$

for all $i, k, j = 1, .., N$. Given (18)-(19), Airline $\mathcal{A}$'s punishment profit becomes

$$\pi^{Pun}_{\mathcal{A}} = \frac{1}{\beta}\Big(\frac{S}{2}\Big)^2\Big(\frac{3N+3}{4}\Big) + \frac{1}{\beta}\Big(\frac{S-\theta}{2}\Big)^2\Big(\frac{3N}{2}\Big) - 2NF > 0. \tag{20}$$

Finally, using (8), (17) and (20), Airline $\mathcal{A}$'s incentive constraint (1) must satisfy the following inequality in a subgame perfect equilibrium:

$$\frac{1}{\beta}\Big(\frac{S}{2}\Big)^2\Big[\frac{2N+1-\delta(3N+2)}{4(1-\delta)}\Big] + \frac{1}{\beta}\Big(\frac{S-\theta}{2}\Big)^2\Big[\frac{N(4-6\delta)}{4(1-\delta)}\Big] - \Big[\frac{2NF}{1-\delta}\Big] \leq 0.$$

The discount factor which sustains a noncooperative collusive outcome under complete liberalisation, δ_c, is given by

$$\delta_c \geq \frac{S^2(2N+1) + 4N(S-\theta)^2 - 32NF\beta}{S^2(3N+2) + 6N(S-\theta)^2}.$$

This result suggests the following remarks:

1. Since $\delta_c > 0$, in equilibrium $F < \frac{1}{32N\beta}[S^2(2N+1) + 4N(S-\theta)^2] \equiv F^*$ [24]. Therefore, the model allows for fixed costs but these must not be excessively high[25]. Notice that when this condition is satisfied, both profit functions (17) and (20) are positive.

2. It is easy to verify that as F increase, $\delta_c(\cdot)$ decreases monotonically, suggesting that for a given collusive outcome the required discount factor becomes smaller as the fixed cost per leg increases.

[24] It can be shown that the threat is credible for fixed costs, F, lower than F^*.

[25] This upper bound is not binding for a large range of parameters.

3. For $N \neq 0$ and/or $F \neq 0$, δ_c is a function of the underlying parameters of the demand and cost functions and the number of domestic legs.

The relation between $\delta_c(\cdot)$ and N turns out to be important for the analysis that follows. Assume that the network is sufficiently large to allow us to treat N as a continuous variable. We can show that, in equilibrium,

$$\frac{\partial \delta_c}{\partial N} = \frac{S^2[S^2 + 2(S-\theta)^2 - 64F\beta]}{[S^2(3N+2) + 6N(S-\theta)^2]^2} \geq (<) 0.$$

Therefore, two cases should be considered:

<u>CASE I: Low Fixed Cost</u> $\qquad F < \frac{1}{64\beta}[S^2 + 2(S-\theta)^2] \equiv F^{**}.$

In CASE I, $F < F^{**}$ and, as N increases, the discount factor, δ_c, required for the trigger strategy to form a subgame perfect equilibrium increases. This suggests that, for sufficiently small entry costs, when cabotage rights are granted to flag-carriers, the larger the network the more difficult it is to sustain collusion. In other words, the stability of the bilateral agreements is more difficult to attain when, ceteris paribus, multi-market flag-carriers operate <u>large</u> h-a-s networks and fixed costs associated with entry are <u>small</u>.

<u>CASE II: High Fixed Cost</u> $\qquad F > \frac{1}{64\beta}[S^2 + 2(S-\theta)^2] \equiv F^{**}.$

In CASE II, $F > F^{**}$ and, as N increases, the discount factor, δ_c, required for the trigger strategy to form a subgame perfect equilibrium decreases. Consequently, an opposite conclusion to CASE I ensues: For fixed costs higher than F^{**}, the larger the network, ceteris paribus, the easier it is to sustain some degree of cooperation.

I am now able to summarize the preceding results and to state the following proposition:

Proposition 1 *Under CASE I, the scope for sustainable collusion with a trigger strategy is strictly larger under partial liberalisation (as defined in Section II). The opposite result is obtained under CASE II: The scope for sustainable collusion with a trigger strategy is strictly larger under complete liberalisation (as defined in Section II).*

Corollary 1 *When $F = 0$, the range in which flag-carriers can sustain collusive equilibria is always larger under partial liberalisation. If $N = 0$ and/or $F = F^{**}$, the most collusive outcome is sustainable if the discount factor is larger than 1/2 under* <u>*both*</u> *regulatory regimes. Notice that when $N = 0$, flag-carriers do not operate domestic legs and, as a consequence, cabotage rights are* <u>*not*</u> *effective: Partial and complete liberalisation outcomes are identical.*

The proof consists in comparing the discount factors, δ_c and δ_p, required for the trigger strategy to form a subgame perfect equilibrium.

Proof 1

$$\begin{aligned}
\delta_c \geq (<)\delta_p \quad &\Longleftrightarrow \quad \frac{S^2(2N+1) + 4N(S-\theta)^2 - 32NF\beta}{S^2(3N+2) + 6N(S-\theta)^2} \geq (<)\frac{1}{2} \\
&\Longrightarrow \quad NS^2 + 2N(S-\theta)^2 - 64NF\beta \geq (<)0 \\
&\Longrightarrow \quad F \leq (>)\frac{1}{64\beta}[S^2 + 2(S-\theta)^2] \equiv F^{**} < F^* \quad \square.
\end{aligned}$$

Notice that in equilibrium, for $N \neq 0$, it is always verified that $F^{**} < F^*$. In effect:

$$\begin{aligned}
F^* > F^{**} \quad &\Longleftrightarrow \quad \frac{1}{32N\beta}[S^2(2N+1) + 4N(S-\theta)^2] > \frac{1}{64\beta}[S^2 + 2(S-\theta)^2] \\
&\Longrightarrow \quad S^2(3N+2) + 6N(S-\theta)^2 > 0, \quad \text{which is always true.}
\end{aligned}$$

Thus, in CASE II, the upper and lower bounds on F are given by $F^* > F > F^{**}$.

Finally, it is interesting to note that the collusive outcome is not always socially undesirable. In particular, it can be shown that under complete liberalisation net social welfare[26] is larger under the collusive outcome *when* fixed costs are higher than $\frac{3}{64N\beta}[S^2(N+1)+2N(S-\theta)^2] \equiv F^w$ [27]. This happens because during the punishment phase (competitive phase), the fixed costs incurred by all flag-carriers lead to productive inefficiencies throughout the network. Given the absence of fixed costs associated with entry into intra-European legs, the collusive outcome is clearly not socially desirable under partial liberalisation.

In summary, the results of Proposition 1 suggest that, *under low fixed costs*, complete liberalisation is more likely to promote competition since a collusive outcome is more difficult to sustain, especially when the network is large. In contrast, *for high fixed costs* the analysis reveals that complete liberalisation provides a relatively larger opportunity to sustain collusion (even if tacit collusion is pervasive under partial liberalisation). Consequently, a simple EU policy implication of this paper could be stated as follows: Grant cabotage rights, i.e., complete liberalisation. If barriers to entry are significant, then work towards reducing fixed costs and institutional barriers.

III.3 Illustration and Numerical Example

In order to illustrate these results, let us first consider the following figures. Figure 2 and Figure 3 (see Appendix) exhibit the profile of required discount factors, as a function of the number of domestic legs. Since N is a positive integer, $\delta_c(\cdot)$ is a step function. As shown in Figure 2, $\delta_c(\cdot)$ increases at a decreasing rate under CASE I. Under CASE II, $\delta_c(\cdot)$ is a decreasing function as can be observed in Figure 3.

Figure 4 (see Appendix) exhibits the range of equilibria for the intermediate case where $F = F^{**}$. As suggested by Corollary 1, the most collusive outcome is sustainable if the discount factor is larger than 1/2 under both regulatory regimes.

[26] Defined as the sum of consumers' surplus on each market xy plus the economic profit of the industry.

[27] To obtain this result, one must compare welfare under collusion with welfare under retaliation over the entire network. Note that for $N \neq 0, F^w < F^*$, in equilibrium.

Figure 5 (see Appendix) exhibits the range of equilibria as a function of F when $N = N_0 > 0$. For a given number of domestic markets, δ_c decreases monotonically as F increases.

Table I provides a numerical example for $\beta = 1, \alpha = 10, \theta = 2$, and $N = 0, 1, 2, 3, 4$. In that case, $F^{**} = \frac{17}{8} = 2.125$. Accordingly, CASE I would correspond to, e.g., $F = 1$, while CASE II would correspond to, e.g., $F = 3$.

Table I: Numerical Example

	CASE I $1 = F < F^{**} = \frac{17}{8}$	$F = F^{**} = \frac{17}{8}$	CASE II $3 = F > F^{**} = \frac{17}{8}$
$N = 0$	$\delta_c = \delta_p \geq \frac{1}{2}$	$\delta_c = \delta_p \geq \frac{1}{2}$	$\delta_c = \delta_p \geq \frac{1}{2}$
$N = 1$	$\delta_c \geq \frac{38}{67}$ and $\delta_c > \delta_p \geq \frac{1}{2}$	$\delta_c = \delta_p \geq \frac{1}{2}$	$\delta_c \geq \frac{30}{67}$ and $\delta_c < \frac{1}{2} \leq \delta_p$
$N = 2$	$\delta_c \geq \frac{34}{59}$ and $\delta_c > \delta_p \geq \frac{1}{2}$	$\delta_c = \delta_p \geq \frac{1}{2}$	$\delta_c \geq \frac{26}{59}$ and $\delta_c < \frac{1}{2} \leq \delta_p$
$N = 3$	$\delta_c \geq \frac{98}{169}$ and $\delta_c > \delta_p \geq \frac{1}{2}$	$\delta_c = \delta_p \geq \frac{1}{2}$	$\delta_c \geq \frac{74}{169}$ and $\delta_c < \frac{1}{2} \leq \delta_p$
$N = 4$	$\delta_c \geq \frac{32}{55}$ and $\delta_c > \delta_p \geq \frac{1}{2}$	$\delta_c = \delta_p \geq \frac{1}{2}$	$\delta_c \geq \frac{24}{55}$ and $\delta_c < \frac{1}{2} \leq \delta_p$

IV Conclusion

We have established under what conditions a trigger strategy can be sustained under both regulatory regimes. We have demonstrated that, for sufficiently low fixed costs, to be precise $F < F^{**}$, flag-carriers are more likely to sustain noncooperative collusive outcomes under partial liberalisation of the European airline industry. When fixed costs are nil, the range of discount factors over which tacit collusion can be sustained is always larger under partial liberalisation. We have shown, concomitantly, that when fixed costs associated with entry into domestic legs are high, $F > F^{**}$, the discount factor required to sustain the trigger strategy equilibrium is, ceteris paribus, lower under complete liberalisation. In this latter case, the high fixed costs act like a natural entry deterrent and flag-carriers are less eager to exploit new entry opportunities provided by the liberalisation of the industry. This appealing result is congruent with standard oligopoly theory. Flag-carriers that repeatedly meet each other in different markets are aware of their "spheres of influence", spheres where they have an absolute or relative cost advantage, and recognise that an entry with high fixed costs would not be privately profitable.

Moreover, we have highlighted an interesting relationship between the size of the network and the ease of sustaining collusion. When fixed costs are low, the larger the domestic network the higher the discount factor required for sustaining collusion, while when fixed costs are high, the larger the network the lower the discount factor required for sustaining collusion. This result implies that for large networks and large fixed costs, collusive outcomes are easier to sustain in equilibrium.

There are some interesting policy implications. First, Section III.1 suggests that flag-carriers have large opportunities for sustaining collusion, given the low threshold of δ_p, under partial liberalisation. This is due to the fact that, in this three-airline model, as a flag-carrier enters into one intra-European leg (one market) it hurts simultaneously two rivals, which are supposed to retaliate. Consequently, the flag-carrier which decides to enter in that leg, expects to be hurt in two legs (two markets). This is an inherent implication of the seventh freedom competition in the European airline industry. Second, Section III.2 shows how fixed costs play an important role under complete liberalisation, given that a flag-carrier is likely to have a competitive advantage in its domestic leg. Fixed costs may be high as a result of a flag-carrier's airport and/or route dominance. We have found that, for a given number of domestic legs operated in the network, the lower the fixed costs, the higher is the incentive to enter and deviate from past bilateral agreements. Complete liberalisation provides the opportunity to operate a larger network so that reaping general short-run gains (i.e., deviating) could turn out to be a successful strategy when fixed costs are low and flag-carriers have relatively high impatience. If fixed costs are high, the incentive to deviate is, ceteris paribus, lower and collusion is more likely to be sustained under complete liberalisation.

Thus, even if complete liberalisation of the European airline industry gives the opportunity to any EU airline to have access to any intra-EU routes, it may be the case that airlines are better off sticking to past bilateral agreements. This is more likely to occur when airlines operate large domestic networks and it is costly to run a new business into rivals' domestic niches. Clearly, institutional constraints on the European airline industry, like congested airports and air space, raise the fixed costs associated with entry. Many airline experts recognise that the shortage of airport capacity is likely to put incumbent flag-carriers in a much better opportunity to block entry by purchasing or leasing most of the gates at the home airport, thereby raising rivals' fixed costs. Furthermore, as stressed by Borenstein [1992], the potential for home-country bias is intensified in this industry because so much of the infrastructure needed by airlines is publicly provided. In fact, Borenstein [1992] argues that the commercial success of an airline entry into a new leg depends on local governments and local airport managers who can play a substantial role in determining key features such as the use of airport facilities, convenience of connections, etc.. Our results suggest that barriers to entry into domestic niches should be minimised if EU authorities or national governments want to promote competition (or restrict noncooperative collusion) in this industry. To this end, any removal of institutional barriers could provide a signal for flag-carriers to act more competitively.

Finally, for relatively high fixed costs, $F^w < F < F^*$, the collusive outcome is not socially undesirable under complete liberalisation because competition leads to high productive inefficiencies.

The main results of the paper hold under a variety of different demand and cost structures because they are driven by the network h-a-s structure and by the fixed costs associated with entry[28]. The analysis could be extended in several directions. First, it would be interesting to analyse how the range of discount factors is modified with (product) air service differentiation. Second, some asymmetries could be introduced such as different city-pair market growth rates, (for example, intra-European markets could grow at a higher rate than domestic markets), different marginal costs and/or different network sizes among flag-carriers. Third, the model could allow for entry into the network by

[28]Whether a particular regulatory scheme enhances flag-carriers to sustain collusion remains an interesting but difficult question to answer *when* cost complementarities arise. In fact, when returns to density are increasing it may well be the case that the range in which flag-carriers can sustain collusion is more important under both regulatory schemes, because of the (negative) effects an entry could induce throughout the network. Further research is clearly needed.

smaller (regional) airlines. A smaller airline could incur additional (sunk) costs with respect to incumbent flag-carriers. Finally, one might test to what extent the European airline industry actually is in the "mutual forbearance" equilibrium described above.

As a final remark, throughout the paper I have assumed that flag-carriers always seek profit maximisation. This is clearly a strong assumption for flag-carriers which are partly or entirely publicly owned. However, the successful privatisation of the largest European flag-carrier, British Airways, has seemed to speed up the privatisation of most European flag-carriers (e.g., Lufthansa) and, as a consequence, one might suppose that profit maximisation becomes a reasonable objective. Having said this does not prevent me from thinking that, in this industry, the economics of national pride are still at work.

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Appendix

Figure 1: Range of Equilibria for δ_c and δ_p under CASE I.

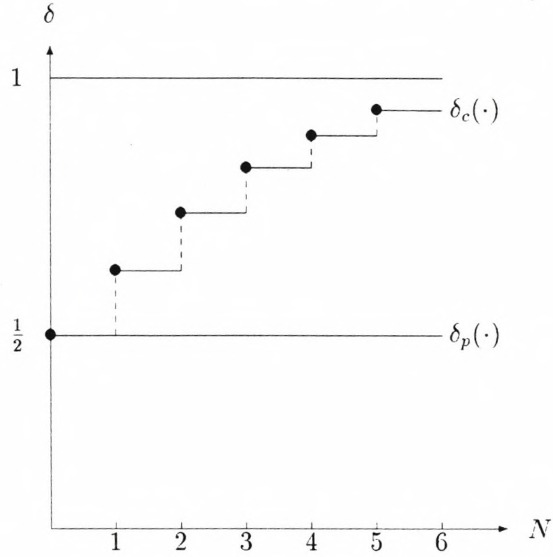


Figure 2: Range of Equilibria for δ_c and δ_p under CASE II.

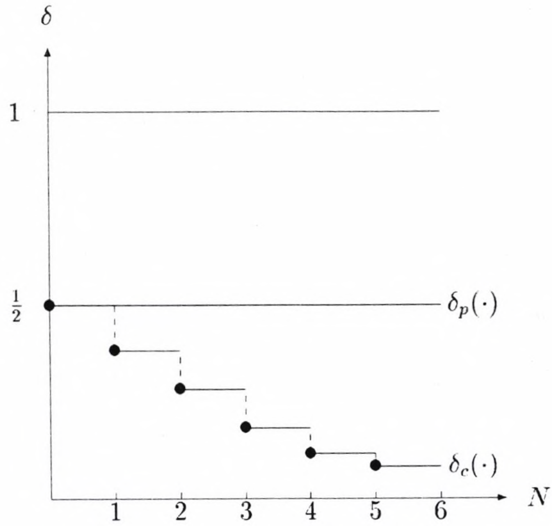


Figure 3: Range of Equilibria for δ_c and δ_p when $F = F^{**}$.

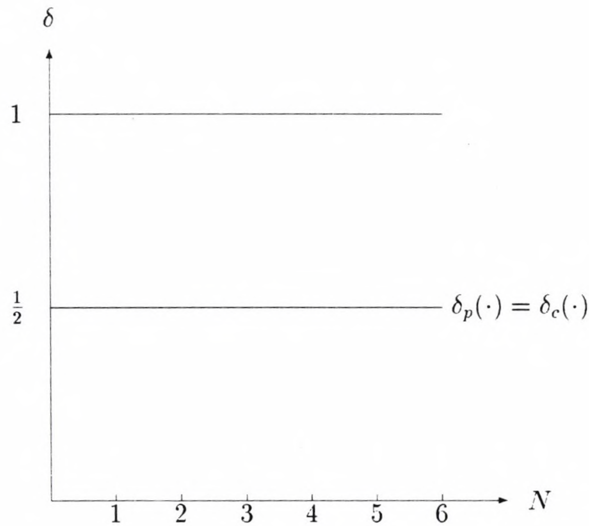
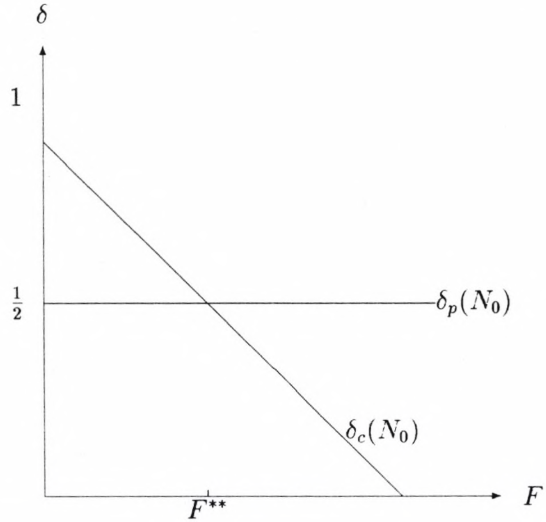


Figure 4: Range of Equilibria for δ_c and δ_p as a Function of F.



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